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Under the shadow of the future: Gender-specific reactions to (un)certain future interactions

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Abstract

Expectations are a key element of strategic environments. As it has already been shown that men's performance in current competitions is affected by the expected future opponents' strength, we investigate whether women are overshadowed by future competitors as well. We use data from professional tennis, replicate the results for men and compare it with women's behavior. Extending previous research, we focus on the role of uncertainty in this context, particularly, whether behavior differs when individuals have to form expectations instead of having accurate information. Our results suggest that individuals perform worse in competitions if the expected future opponent is stronger. We find gender-specific behavior when analyzing uncertainty as a potential source: Women's current performance does not depend on the future competitor's strength when they know her for sure, whereas they are overshadowed when having to form expectations. In contrast, men are negatively affected by the future competitor's strength when they know him and when they need to form expectations. Moreover, women (men) rather seem to be sensitive to direct (more distant) incentives. These findings might be transferred to information revelation in promotion contests to help highly qualified individuals, especially women, climb the career ladder.

1 | MOTIVATION

Despite the increasing number of high-qualified women, they are still underrepresented in leading positions. For instance, in 2017, the share of women on corporate boards of the largest listed companies in the European Union amounted to 25.3% (EU & EC, 2018). Reasons have been seen in female preferences, such as labor force participation, human capital formation, and occupation choice, but also in discrimination of employers against women (see, e.g., Black & Strahan, 2001; Goldin & Rouse, 2000).¹ Some recent studies have focused on a different component, particularly, women's psychological traits including their willingness to enter competitions. Although no performance differences exist, women are less inclined than men to enter competitions, which might contribute to explain gender differences in labor market outcomes (see, e.g., Niederle & Vesterlund, 2007).

Nowadays, there is an intense discussion about how to close the gender gap in labor market outcomes. Several papers focused on strategies that induce women to enter competitions and discuss affirmative action policies that lead

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to more competition entry, especially for high-performing women (see, e.g., Balafoutas & Sutter, 2012; Gneezy et al., 2003). Moreover, it has already been shown that information about their competitor's past performance reduces gender differences in competition entry (Ertac & Szentes, 2011; Wozniak, 2012).

However, it is not only initial competition entry but also subsequent competition, for example, promotions or other performance-based rewards, that determine whether women climb the career ladder. As promotions equal competitions and employers aim to promote the most capable individual, it is important to investigate women's behavior when they are already inside the competition. Apart from the current opponent's ability, which is negatively correlated with the own effort, also expectations about the strength of the future opponent might impact current behavior, which has already been shown for male basketball players (Lackner et al., 2015). Moreover, Brown and Minor (2014) show theoretically that the winning probability of a favorite is lower in case that the expected opponent in the next round is stronger (shadow effect) and in case that they had to exhibit higher effort in the past (spillover effect). Their theoretical predictions are supported by an empirical analysis based on tennis tournaments of male players.

Yet, it remains an open question whether such shadow effects are gender-specific and whether information precision about future competition plays a crucial role in the size of the shadow effect. As there are gender differences in the decision to enter a competition, it might well be that also women's reaction to competitive pressure differs from men's. Transferred to a corporate perspective this means that career prospects depend on future competitions, for example, individuals might be discouraged when they expect high-qualified rivals in the later stages of their careers. When men and women differ in their reactions to anticipated future competition, this might contribute to explain why fewer women climb the career ladder leading to lower relative wages of women. Moreover, it might well be that men and women react differently when information about future competition is associated with some degree of uncertainty. Such knowledge might lend practical advice about whether to reveal information about later competitors.

We contribute to previous research by analyzing (1) gender differences with respect to spillover and shadow effects and (2) uncertainty as a potential source of the shadow effect. In particular, in the first part of our analysis, we tie up to Brown and Minor (2014) and replicate their analysis for both, men and women. In contrast to their analysis that relies on data from males only, we additionally include data from females which enables us to identify gender-specific behavior. Specifically, we investigate how men's and women's current winning probabilities depend on (i) the strength of the expected future opponent and (ii) their effort in previous rounds. In doing so, we complement existing research as we focus on the impact of future competition on women that already entered a competition, which might help explain how female careers develop over stages.

Our first set of results suggests that there is a shadow effect for men and women of similar size. We also find negative spillover effects for men and women. Interestingly, behavior turns out to be gender-specific with respect to immediate and more distant incentives. First, we find a long shadow for male players, that is, a negative effect of the best player's rank (in the tournament) on the favorite's winning probability, whereas there seems to be no such effect for women. Second, monetary incentives in the form of total prize money in a tournament seem to be important only for men. In contrast, direct monetary incentives in the form of prize money differences between winner and loser have a negative impact only on female favorites. Hence, the behavior of men is completely in line with Brown and Minor's (2014) results for men, whereas women's behavior deviates in these two respects. This suggests that women rather seem to be sensitive to immediate consequences instead of potential events in the far future. In contrast, men seem to care more about the big picture.

In the second part of our analysis, we furthermore extend the study by investigating the role of uncertainty about the future opponent, particularly, our data set includes two states of information: future opponents are either known or unknown (but individuals can form expectations). In fact, our second set of results suggests an interesting gender difference. For women, the shadow effect is driven by uncertainty. Specifically, when women know their future opponents for sure, the shadow effect vanishes. For men, the shadow effect becomes smaller when they know their future opponent for sure, however, in contrast to women, the shadow effect still exists. Interestingly, knowing whether the future opponent is weaker than expected does not change the results. Hence, we conclude that the most important determinant for the shadow effect is (un)certainty about the future opponent.

Our results have important implications as they might help promote highly qualified individuals. According to our findings, revealing information about future competitors might be especially beneficial for highly qualified women. This holds at least in single-gender competitions.

The paper is organized in the following way. In Section 2, we give an overview of two related strands of the literature: gender differences in economic decisions as well as the role of information in competitions and strategic situations in general. Subsequently, the data set and hypotheses are presented, followed by the results and a conclusion.

2 | RELATED LITERATURE

2.1 | Gender differences in competitions as explanation for labor market outcomes

A large number of researchers study gender differences in economic decisions and social preferences in general, and competitive behavior in particular.² Existing evidence suggests that men and women differ in both, their preferences to enter competitions as well as their reaction to competitive pressure. Specifically, men are more likely to enter competitions than women (e.g., Datta Gupta et al., 2013; Dohmen & Falk, 2011; Niederle & Vesterlund, 2007) and react positively to competitive pressure by increasing their performance, whereas women do not perform better in a competitive environment (e.g., Gneezy et al., 2003; Iriberry & Rey-Biel, 2019; Ors et al., 2013). In line with these findings, Buser et al. (2014) find that men choose more competitive, and prestigious career paths (maths and science) than women. Importantly, women's inclination to competition and their confidence are actually predictive of their compensation (Kamas & Preston, 2018; Manning & Swaffield, 2008). Specifically, confident women who are prone to compete earn as much as men and much more than other women.

As this might contribute to reducing gender differences in labor market outcomes, the question of how to close this gender gap in competition arises. Several recent papers focus on affirmative action policies and show that quotas can make women (especially high-performing women) enter competitions (see, e.g., Balafoutas & Sutter, 2012; Gneezy et al., 2003). However, the existing literature tends to neglect how women proceed after winning such a tournament. For instance, there might be no appreciation for women who win a tournament under affirmative action policies, or women may perform poorly in future competitions, such as promotions. In a similar fashion, women might be punished for entering a competition. In particular, Bowles et al. (2007) show that women are evaluated more negatively for initiating negotiations, whereas men are not. Moreover, Mueller and Plug (2006) find that men are rewarded for being disagreeable, but women are not. In line with these findings, Sarsons et al. (2021) demonstrate that men are tenured also for group work, whereas women are not. Therefore, it is important to further investigate gender-specific behavior after entering a competitive environment. For instance, Buser (2016) as well as Gill and Prowse (2014) study reactions to past wins and losses and find that women seem to be more discouraged by past losses than men. Yet, it has not been investigated so far whether women are also discouraged by stronger future competition, which is especially relevant for information revelation about future competitors.

Information is in a number of ways a crucial factor that drives gender differences in competitive behavior. Most studies focus on information about past and current competition and find that gender differences in competition entries disappear when individuals can condition competition entry on information, such as competitor's past performance (see, e.g., Ertac & Szentes, 2011; Wozniak, 2012). On the basis of a large-scale experiment on a job-posting website, Gee (2019) supports this finding and concludes that women react more to information than men, that is, women can be encouraged to enter competitions by providing additional information. In line with these findings, the results by Balafoutas and Sutter (2019) indicate that men benefit more from uncertain situations than women. In particular, men and women enter tournaments more often under uncertainty with respect to the number of winners (probabilities of the number of winners known) and ambiguity (probabilities of the number of winners unknown), but the effect is more pronounced for men. Moreover, men tend to increase their performance after entering a competition under uncertainty or ambiguity, whereas women do not.

Overall, results of previous studies on gender differences in competitive environments suggest that information about the future competitor might be of great importance for explaining gender-specific competitive behavior. We hence complement previous research by systematically analyzing how certain and expected future competitors impact current competition.

2.2 | Importance of past, current, and future interactions for strategic decisions

A number of recent studies address competitive behavior, particularly, how information about competitors enters strategic decisions, such as effort provision. Importantly, this impact crucially depends on the stage or point in time of the competition. In particular, it is not only one's own and competitor's current performance, but also past performance as well as future competition that determine current behavior in competitions.

First, past competition enters current competition as it determines the current ranking and (perceived) ability differences of competitors (i.e., whether a player or team is considered stronger or weaker). In particular, own effort is

negatively correlated with the opponent's ability (Lackner et al., 2015), and competition intensity is lower in heterogeneous contests or when a superstar is involved (e.g., Berger & Nieken, 2016; Brown, 2011; Sunde, 2009).

Apart from rankings, positive or negative effort spillovers impact current competition. On the one hand, having invested more effort in a previous stage can lead to negative spillovers due to fatigue, that is, performance in the current stage is worse, which is more pronounced for individuals (e.g., Brown & Minor, 2014; Goossens et al., 2015).³ On the other hand, positive effort spillovers that might arise from increased motivation or momentum are especially important in team contests, that is, when a team plays more games in the current season, the winning probability for subsequent games is higher (Hill, 2018). Interestingly, some recent studies confirm that athletes manage their power over stages of a contest, meaning that depending on the heterogeneity of the match, the stronger athletes save effort for subsequent rounds (Deutscher et al., 2019; Harbaugh & Klumpp, 2005).

Second, the proceeding of the match also affects the current competition. Existing literature suggests that individuals adjust their (strategic) behavior during a competition. For instance, a well-documented phenomenon is discouragement, that is, the lagging player further reduces performance (e.g., Iqbal & Krumer, 2019; Malueg & Yates, 2010).⁴ Consistently, players who lag behind (are leading) take more (less) risky strategies (Ozbeklik & Smith, 2017). Moreover, both teams lower their effort when the current state of a contest suggests that it is already decided (Schneemann & Deutscher, 2017).

Third, future competition might impact current competition, on which we are focusing in our study. Closely related to our work, Brown and Minor (2014) set up a model to demonstrate how the winning probability of the stronger player in a specific stage of an elimination tournament is affected by the strength of the expected future opponent in the next stage. The authors test their predictions for male tennis players and find that the winning probability of a male stronger player is affected by both, past and future competition. Specifically, when the expected future opponent is stronger, the winning probability of the stronger player decreases. Interestingly, this effect is found to be already incorporated into betting markets. The existence of such a shadow effect is further supported by Lackner et al. (2015), who use data from male basketball players and find that current effort is higher when chances to stay in the tournament are higher. Consistently, Hill (2018) confirms a shadow effect for male basketball teams and additionally considers whether future opponents are known for sure or expected. In case the future opponent is known and weaker than expected, the winning probability of the stronger team increases (lending further support for the existence of a shadow effect). Deviating from Brown and Minor (2014), he further finds that betting markets do not properly incorporate these effects.

We use data from the Association of Tennis Professionals (ATP) and Women's Tennis Association (WTA) tour over a period of 10 years to study whether shadow effects are gender-specific.⁵ Up to now, data from professional tennis has been used in previous studies that analyze the driving forces of competitive behavior, for instance, monetary incentives. Gilsdorf and Sukhatme (2008) find that higher prize money differentials in women's tennis affect the winning probability of the stronger player positively. Moreover, Iqbal and Krumer (2019) find that intermediate prizes (points in Davis Cup) lead to a disappearance of the discouragement effect for men, whereas there is no such study for women. Also, González-Díaz et al. (2012) use point-level data from male tennis matches and find that the individual ability to adapt performance to the importance of the situation, that is, reaction to pressure, is a crucial predictor for overall career success in tennis.

Overall, previous studies that use tennis data for analyzing gender differences indicate more strategic behavior of men, but they also tend to behave more unethically (with respect to collusive behavior) than women (Anbarci et al., 2016; Jetter & Walker, 2017).⁶ With regard to choking under pressure, Cohen-Zada et al. (2017) find supporting evidence for men, whereas there is no clear evidence for women. In contrast, Paserman (2007) finds the probability of winning a point to decrease for men as well as women when the point is more important, whereas the ratio of unforced errors to winning shots increases only for women. In accordance, De Paola and Scoppa (2017) find that women rather than men choke under pressure, that is, psychological pressure seems to be high only for lagging females (which is more pronounced for higher stakes). Moreover, a positive momentum effect within a match seems to exist only for men (Gauriot & Page, 2019; Page & Coates, 2017). In particular, men's probability of winning a particular point or set is higher when they already won the preceding point or set, whereas this does not apply to women. Finally, there seem to be no gender differences in fatigue that lead to spillover effects between matches. Both, female and male stronger players' winning probability decreases when having played more sets than their opponent in the previous match (Goossens et al., 2015).

We complement previous studies by focusing on women who have already entered a competition. Particularly, we tie up to Brown and Minor (2014) (called BM in the following) and first replicate their analysis using data for both,

male as well as female players. We then extend their analysis and investigate whether shadow effects depend on the information precision about the future opponent, that is, whether he/she is known or unknown. This gives insights into the role of uncertainty in the context of shadow effects. Thus, we contribute to previous research regarding gender differences in competitive behavior, which might help explain labor market outcomes and provide advice for policy implications, such as whether or not to provide specific information about future competitors. While focusing on within-gender competitions, our analysis forms an important basis for studying between-gender competitions.

3 | DATA AND DESCRIPTIVE STATISTICS

Our data set includes information about matches and players of the four grand slams (Australian Open, French Open, US Open, and Wimbledon) as well as the men's ATP Tour Masters 1000 (henceforth ATP1000) and women's Premier Mandatory WTA tour (henceforth PM WTA) for the period from 2008 to 2018, which we collected from <http://www.tennis-data.co.uk>.⁷

These tournaments belong to the class of single-elimination tournaments, meaning that the winner of a specific match advances to the next stage whereas the loser is kicked out of the tournament. The tournaments are played over six or seven rounds.⁸ Hence, the first round of a seven-round tournament includes 64 matches (with a total of 128 players), whereas the first round of a six-round tournament consists of 32 matches (64 players).⁹ All winners, hence, half of the players (64, resp., 32), advance to the second round and are then eliminated in subsequent rounds until only two players are left in the final. The winner of the final is eventually the overall winner of the respective tournament. Grand slams, ATP1000, and PM WTA are high-stakes tournaments with total prize money for a grand slam ranging from \$46 million to \$62.5 million in 2019.¹⁰ The prizes are generally the same for both gender and increase with progressing rounds. For instance, a first-round winner of a grand slam already receives slightly more than \$50,000, whereas the tournament-specific prize for the overall winner ranges from \$2.6 million to \$3.8 million (in 2019). As the prize is higher in the subsequent round, there is a strong incentive for players to win. Importantly, the prizes for each tournament are publicly known before the tournament starts. Apart from money, players receive points that impact their world ranking.¹¹ Thus, we proxy the player's ability by the world ranking (in line with BM).

Moreover, players' world ranking affects the draw of the tournaments. In particular, the top player is seeded in the upper half of the draw, whereas number two is seeded in the lower half of the draw, meaning that they can only meet in the final. Number three and number four are also placed in different halves of the draw to ensure that the four best players only meet in the semifinals. The number of seeded players is either 32 (for seven-round tournaments) or 16 (for six-round tournaments). The rest of the players are set randomly to the remaining seeds. Thus, stronger (better-ranked) players play against a range of opponents with different ability levels. This randomization allows us to correctly estimate how the stronger players' winning probability depends on the specific circumstances of the match, particularly, to estimate shadow and spillover effects.¹²

A tennis match consists of points, games, and sets. The player who first wins four points wins a game. To win a game a player has to be two points apart, that is, if both players won three, five, seven, and so forth the game is continued until one of the players wins points at a distance of two. The player who first reaches six games wins a set. A distance of two is also required for winning a set, that is, in case both players win five games, the set is extended to seven games. In case both players win six games, a so-called tiebreak is played (a game that is won by the player who first reaches seven points at a distance of two). Finally, the player who first wins three (two) sets wins the match when it is played according to a best-of-five (best-of-three) rule. Whereas men's grand slam tournaments are played according to a best-of-five rule, all other matches included in our data set are played according to a best-of-three rule.

There is evidence that the degree of certainty about information impacts individual decision-making (e.g., Lackner et al., 2015), thus, it might well be that also shadow effects depend on the foreseeability. For this reason, we extend BM's analyses and consider three cases: the future opponent's match is already finished before the start of the own match (future opponent's rank is known), the future opponent is playing at the same time (the future opponent's rank is only known at some point during the own match), and the future opponent's match starts after the own match (future opponent's rank is unknown). To compute this information, we extract data about the starting time of matches from <http://www.scorespro.com/tennis/> (scorespro, 2020). Data about match duration is taken from Jeff Sackmann (<https://github.com/JeffSackmann/>).¹³ If we do not have information about match duration, we consider an opponent's match to be finished if the difference in starting times is larger than 3 h (2 h) for matches played according to the best-of-five (best-of-three) rule.¹⁴



Overall, our data set thus includes match-level information for men and women from 44 grand slam tournaments each (11,087 matches), 99 tournaments (6120 matches) from ATP1000, and 43 tournaments (3288 matches) from the PM WTA tour. The summary statistics of the data are depicted in Table 1.

Male stronger players win 69.9% of the matches, whereas female stronger players win 68.0% of the matches. This is well in line with BM's findings for male stronger players who win 62.9% (six rounds), respectively, 68.9% (seven rounds), of the cases.¹⁵

On average, matches are finished after 22.9 games for men and 21.4 games for women if the match is played according to a best-of-three rule. Moreover, a third decisive set needs to be played in 34.9% (31.8%) for men (women).

TABLE 1 Summary statistics.

	Men			Women		
	Total	Grand slam	ATP1000	Total	Grand slam	PM WTA
Number of tournaments	143	44	99	87	44	43
Number of matches total	11,664	5544	6120	8831	5543	3288
1st round	5264	2816	2448	4126	2816	1310
2nd round	3344	1408	1936	2439	1407	1032
3rd round	1672	704	968	1216	704	512
4th round	528	352	176	528	352	176
Quarterfinal	572	176	396	348	176	172
Semifinal	284	88	196	174	88	86
Means						
% of matches in which	69.9	73.4	66.8	68.0	69.7	65.2
stronger player wins	(45.86)	(44.17)	(47.11)	(46.65)	(45.96)	(47.66)
Betting market prediction	80.0	81.5	78.7	71.8	73.1	69.6
that stronger player wins (in %)	(25.45)	(24.35)	(26.33)	(17.49)	(17.97)	(16.42)
Expected future opponent's rank	23.2	31.6	15.7	26.6	32.6	17.3
	(26.19)	(31.84)	(16.39)	(26.64)	(30.55)	(13.95)
Future opponent's rank	34.4	46.2	23.8	40.8	48.9	27.1
	(49.77)	(60.95)	(33.42)	(54.52)	(62.83)	(32.07)
Stronger players' previous games	20.5	29.4	12.5	16.6	18.4	13.7
	(31.55)	(38.85)	(19.78)	(23.84)	(24.71)	(21.99)
Weaker players' previous games	26.8	32.3	21.7	19.9	19.6	20.5
	(34.83)	(43.05)	(24.00)	(24.93)	(25.95)	(23.10)
Current rank ratio (worse/better)	8.0	9.4	6.8	7.9	8.7	6.7
	(22.19)	(27.92)	(15.14)	(16.63)	(18.18)	(13.53)
Future opponent plays	36.8	17.8	54.6	33.8	23.3	51.6
before (in %)	(48.22)	(38.28)	(49.83)	(47.29)	(42.30)	(49.99)
Future opponent plays	38.7	64.3	15.4	41.1	53.3	20.2
simultaneously (in %)	(48.72)	(47.92)	(36.05)	(49.20)	(49.89)	(40.12)
Future opponent plays	24.5	17.9	30.5	25.2	23.4	28.3
Afterwards (in %)	(42.99)	(38.34)	(46.04)	(43.40)	(42.31)	(45.03)

Note: Standard deviation in parentheses. Finals are not included in the data. If future opponents had a bye in the previous round, the future opponent is categorized as *plays before*. The number of previous games is the aggregated number of games in the tournament. In the first round, it is set to zero.

Abbreviations: ATP, Association of Tennis Professionals; ATP1000, ATP Tour Masters 1000; PM, Premier Mandatory; WTA, Women's Tennis Association.

In the case of a best-of-five match, matches are on average finished after 35.4 games and a fourth or fifth decisive set has to be played in 47.5% of the cases.

Interestingly, we find that the betting market is rather optimistic with respect to the predicted winning probability of male stronger players which equals 80.0%, on average. For female players, the betting market seems to predict the winning probability of stronger players more accurately, that is, in 71.8% of the cases.¹⁶ In comparison, BM found that the betting market predicts the stronger players to win in 62.4% (67.3%) of the cases in six (seven) round tournaments.

One of the key variables in our analysis is the rank of the expected future opponent that represents his/her strength and thus affects the winning probability in the subsequent round. We investigate the shadow effect, that is, whether this rank also affects winning probabilities in the current round. In line with BM, we define the expected future opponent's rank as the rank of the stronger player in the parallel match that determines the future opponent.¹⁷ On average, the rank of the expected future opponent is slightly better (23.2) for men in our data than in BM (25.9, resp., 29.2), which is especially pronounced in the ATP1000 tour. For females, the mean of the expected future opponent's rank is 26.6. Plausibly, the true rank of the future opponent is worse than the expected future opponent's rank as the weaker player wins in roughly 30% of the cases, which holds for men and women.

The rank ratio of men (8.0) and women (7.9) is close to the one of BM (6.7, resp., 9.1). On average, the stronger player has played slightly fewer games in previous matches than the weaker player, which is also in line with BM (in BM the stronger player has played 14.3, respectively, 25.4 games and the weaker player 20.8, resp., 30.0 games). Moreover, the number of previous games is lower for women than for men in grand slams, which is plausible due to the fact that women play according to a best-of-three rule, whereas men play according to a best-of-five rule.

We extend the analyses of BM by focusing on the role of (un)certainly about the future opponent. The future opponent is known, that is, plays before the own match starts, in 36.78% (men) and 33.76% (women) of the matches. In approximately 40% of the matches, future opponents play simultaneously and in roughly 25% of the matches, the future opponent plays afterwards. In both of these scenarios, future opponents are unknown at the beginning of the own match. With respect to the tournament, most matches are played simultaneously in grand slams, whereas most future opponents are known in ATP1000 and PM WTA matches, which can be explained by byes in the first round.

Overall, the differences between men and women in our data seem to be rather small. Most importantly, we find no statistically significant difference between men and women for the rank ratio ($p = .82$, t test). This is important as different rank ratios might distort comparisons of the shadow effect. In contrast, we find significant differences between men and women for the stronger player's previous games and the weaker player's previous games ($p < .01$, t test). However, these differences are rule-based as men in grand slam tournaments play according to a best-of-five rule. Moreover, the winning probability of female stronger players is slightly lower than that of male stronger players ($p < .01$, t test). We account for this difference by including a dummy variable for female players in our subsequent analysis. Hence, gender differences in the winning probability of the stronger player are not problematic.

4 | BEHAVIORAL EXPECTATIONS

A shadow effect for men has already been shown in the study of BM that we first extend by including female players as well. Hence, we state the first hypotheses based on BM's findings. As women generally tend to be less confident and less inclined to competition than men they might be prone to the same effect. Importantly, the expected future opponent's rank in BM's analysis always equals the rank of the stronger player in the parallel match as the authors do not have information to distinguish between known and unknown future opponents. We use their definition in our replication part and later account for uncertainty. Our first hypotheses hence read as follows:

Hypothesis 1. The stronger player's winning probability decreases when the expected future opponent's rank is better. This holds for men and women.

As men compete with men and women compete with women, there is no a priori expectation about gender-specific fatigue. As a spillover effect has already been shown for men, we state the second hypothesis:

Hypothesis 2. The stronger player's winning probability decreases with the number of previously played games. This holds for men and women.



Moreover, we base our third set of hypotheses on BM's alternative specifications that address a long shadow, meaning that the stronger player wins less often when there are very superior players in the tournament, and monetary incentives in the form of total price money. We propose the following hypotheses:

Hypothesis 3a. The stronger player's winning probability is lower when the rank of the best player in the tournament is better. This holds for men and women.

Hypothesis 3b. The stronger player's winning probability increases when the total price money is higher. This holds for men and women.

In line with BM's findings, we furthermore expect that the betting market correctly anticipates the shadow and spillover effect for both, men and women, giving rise to the following hypotheses:

Hypothesis 4a. The betting market anticipates that the stronger player's winning probability decreases when the expected future opponent's rank is better. This holds for men and women.

Hypothesis 4b. The betting market anticipates that the stronger player's winning probability decreases with the number of previously played games. This holds for men and women.

Finally, we explore whether the degree of certainty about the future opponent's strength enters the extent of the shadow effect. In case the parallel match is already decided, the future opponent's rank is known. In case the parallel match is played after the own match, the future opponent's rank is still unknown and the respective player can only form expectations about the winner. If a shadow effect exists, the winning probability of the stronger player should be affected negatively by the strength of the (expected) future opponent in both cases, which holds for both, men as well as women.¹⁸ We thus state our next hypotheses:

Hypothesis 5a. The stronger player's winning probability decreases when the known future opponent's rank is better. This holds for men and women.

Hypothesis 5b. The stronger player's winning probability decreases when the expected future opponent's rank is better. This holds for men and women.

Yet, as expectations most likely include the possibility that the weaker player wins the match, the shadow effect should be stronger in case the future opponent is already certain. We state the following hypothesis:

Hypothesis 5c. The stronger player's winning probability decreases more when the future opponent's rank is better and known. This holds for men and women.

As there is no reason to expect that the spillover effect depends on (un)certainly about the future opponent, we further state the following hypothesis:

Hypothesis 5d. The stronger player's winning probability decreases with the number of previously played games, independently of (not) knowing the future opponent. This holds for men and women.

Moreover, knowing whether the stronger or the weaker player won the parallel match might be relevant for the own match. In particular, when there are surprise victories, meaning that the weaker player won the parallel match, the future opponent might be weaker and vice versa. Knowing about this fact might hence impact the stronger player's winning probability. Therefore, we state our sixth hypothesis:

Hypothesis 6. The stronger player's winning probability is lower when it is certain that the future opponent is the stronger player in the parallel match. This holds for men and women.

5 | EMPIRICAL STRATEGY AND RESULTS

We start our analyses with a replication of BM and extend their analysis by including female players as well. This enables us to uncover whether shadow and spillover effects are gender-specific. Subsequently, we further extend their analyses and differentiate between cases with known future opponents and expected future opponents. Finally, we explore whether surprise victories in the parallel match impact the winning probabilities of stronger players.

5.1 | Shadow and spillover effects for men and women

Replicating the estimation strategy of BM, we estimate the following baseline specification

$$\begin{aligned} \text{StrongerPlayerWins}_{mrt} = & \beta_0 + \beta_1 \text{ExpFutureOppRank}_{mrt} + \beta_2 \text{Female}_{mrt} + \beta_3 \text{PastGamesStrong}_{mrt} \\ & + \beta_4 \text{PastGamesWeak}_{mrt} + \beta_5 \text{RankRatio}_{mrt} + \alpha X_r + \gamma Z_t + \varepsilon_{mrt}, \end{aligned}$$

where $\text{StrongerPlayerWins}_{mrt}$ is an indicator variable equal to one if the stronger player as defined by a better rank (lower numerical value), won the match m in round r and tournament t . We control for the rank of the expected future opponent $\text{ExpFutureOppRank}_{mrt}$ that equals the rank of the stronger player in the parallel match, player's gender, Female_{mrt} , the number of games played in the previous rounds of both, the stronger and weaker players of the match, $\text{PastGamesStrong}_{mrt}$ and $\text{PastGamesWeak}_{mrt}$.¹⁹ To control for players' ability differences, we include the current RankRatio_{mrt} , that is, the rank of the weaker player over the rank of the stronger player. X_r and Z_t denote round-fixed effects and tournament-year fixed effects. The results from the regressions are shown in Table 2, whereby the specifications explained below refer to the respective columns.

We study gender differences in shadow and spillover effects using male and female players. Hence, we extend BM's regression model by including a dummy variable for female players in our baseline specification (1) and an interaction of the female dummy with ExpFutureOppRank in specification (2). Deviating from BM, who run separate regressions for five-, six-, and seven-round tournaments, we use the pooled data and include a dummy variable that indicates whether the tournament is a grand slam tournament or part of the ATP1000, respectively, PM WTA, tour (*GrandSlam*; 1 = grand slam) and an interaction with the rank of the expected future opponent in specification (3).²⁰ To measure the impact of grand slam tournaments, we replace tournament-year fixed effects with detailed tournament controls, particularly, surface-type and court-type²¹ in this specification. Specification (4) includes interactions of the female dummy with PastGamesStrong and PastGamesWeak . In specification (5), we consider a possible long shadow effect (*BestRank*). In line with BM, we consider the rank of the best potential opponent in the tournament generally equals the rank of the best player in the tournament and, for the best player, equals the second-best rank in the tournament. Specification (6) includes an interaction with the female dummy, hence, we can uncover whether men and women react differently to immediate and more distant future competition. In specification (7), we focus on BM's alternative specification, that is, we control for the logarithmic purse of the tournament (LnPurse) and replace tournament-year fixed effects with detailed tournament controls to measure this impact. In specification (8), we extend BM's analysis by controlling for the prize difference between the winner and loser in the respective match, that is, the difference in prize money if the winner advances one round further and is then eliminated ($\text{DiffPrize} = \text{prizewinner} - \text{prizeloser}$). In doing so, we investigate how a change in immediate monetary incentives enters the winning probability. This enables us to uncover whether reactions to immediate and more distant monetary incentives differ.

In line with BM, we estimate all specifications as linear probability models and cluster standard errors at year-specific tournament level. To check the robustness of our results and get a deeper understanding of gender-specific effects, we estimate the same regression models separated by gender.²² Final matches are excluded from all specifications, because they lack information about expected future opponents.

The results support Hypothesis 1, that there exists a shadow effect for men as well as for women. The coefficient of ExpFutureOppRank is positive and significant in all specifications. Specifically, the positive estimate of 0.19 percentage points in specification (1) indicates that a one standard deviation improvement in the rank of the expected future opponent is associated with approximately 5 percentage points lower probability that the stronger player wins the match (5.0/5.1 percentage points for men/women). This estimate is well in line with BM, who find an effect size in the range of 2.2–5.2 percentage points, depending on the number of rounds in the tournament (either six or seven). Moreover,

TABLE 2 Regressions of stronger players' winning probability.

Variables	Dependent variable: Stronger player wins (0% or 100%)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>Constant</i>	62.04*** (0.771)	62.21*** (0.909)	61.44*** (0.753)	61.81*** (0.789)	57.88*** (1.361)	57.36*** (1.521)	19.21* (9.831)	62.28*** (0.625)
<i>ExpFutureOppRank</i>	0.191*** (0.0160)	0.185*** (0.0202)	0.170*** (0.0411)	0.191*** (0.0160)	0.190*** (0.0157)	0.190*** (0.0157)	0.196*** (0.0156)	0.214*** (0.0166)
<i>Female</i>	−2.783*** (0.712)	−3.153*** (1.089)	−2.265*** (0.673)	−2.117** (0.837)	−3.119*** (0.671)	−1.996 (2.048)	−2.390*** (0.698)	−1.526** (0.730)
<i>Female × ExpFutureOppRank</i>		0.0131 (0.0255)						
<i>PastGamesStrong</i>	−0.286*** (0.0336)	−0.287*** (0.0338)	−0.273*** (0.0335)	−0.290*** (0.0375)	−0.283*** (0.0335)	−0.282*** (0.0335)	−0.247*** (0.0348)	−0.204*** (0.0334)
<i>Female × PastGamesStrong</i>				−0.000295 (0.0526)				
<i>PastGamesWeak</i>	0.257*** (0.0347)	0.256*** (0.0346)	0.250*** (0.0350)	0.255*** (0.0384)	0.251*** (0.0339)	0.251*** (0.0338)	0.270*** (0.0349)	0.288*** (0.0369)
<i>Female × PastGamesWeak</i>				−0.0347 (0.0484)				
<i>RankRatio</i>	0.230*** (0.0526)	0.230*** (0.0526)	0.231*** (0.0524)	0.230*** (0.0526)	0.207*** (0.0521)	0.207*** (0.0521)	0.229*** (0.0561)	0.224*** (0.0535)
<i>GrandSlam</i>			5.205*** (1.129)					
<i>GrandSlam × ExpFutureOppRank</i>			0.0184 (0.0417)					
<i>BestRank</i>					4.488*** (1.183)	4.943*** (1.351)		
<i>Female × BestRank</i>						−0.988 (1.676)		
<i>LnPurse</i>							2.835*** (0.640)	
<i>DiffPrize</i>								−0.00513 (0.00626)
Round fixed effects	x	x	x	x	x	x	x	x
Tournament-year fixed effects	x	x		x	x	x		
Surface and court-type fixed effects			x				x	x
<i>Observations</i>	20,369	20,369	20,369	20,369	20,369	20,369	18,657	18,155
<i>R</i> ²	0.047	0.047	0.039	0.047	0.048	0.048	0.037	0.037

Note: Robust standard errors clustered on tournament-year level in parentheses.

*** $p < .01$; ** $p < .05$; * $p < .1$.

specification (2) suggests that there is no markup or discount on the shadow effect for women. Hence, there seems to be a shadow effect for women of about the same size as the one for men.

Result 1. *There exists a shadow effect for women of about the same size as the one for men.*

Replacing year-specific tournament fixed effects with more detailed characteristics of a tournament, that is, surface-type and court-type, and controlling for whether the tournament is a grand slam tournament or part of the ATP1000, respectively, PM WTA, tour (column 3) does not change the results. While the stronger player seems to win more often in grand slam tournaments, the shadow effect does not depend on the class of the tournament.

The regression results also lend support for Hypothesis 2 in favor of a negative spillover effect for both, the stronger and weaker player which replicates BM's findings for men. In particular, when the stronger (weaker) player played more games in previous rounds, the winning probability of the stronger player decreases (increases). In line with BM's estimates of 7.8–13.0, we find that an increase in the number of previously played games by the stronger male player leads to a decrease in the winning probability of 9.1 percentage points. Moreover, we find that an increase by one standard deviation in the weaker player's previous games results in a higher winning probability of the stronger player by on average 8.2 percentage points, which is slightly higher than BM's effect sizes of 7–7.4 percentage points. Again, we find no significant markup or discount for female players which means that men and women are similarly affected by spillover effects. Yet—if anything—women are less affected by spillover effects, particularly, when the number of previous games by the stronger (weaker) player increases by one standard deviation, the stronger player's winning probability is about 6.9 (6.4) percentage points lower (higher).²³ This might be caused by the best-of-five rule often implemented for men which is likely to result in more fatigue than the best-of-three rule implemented for women. Our finding stands in contrast to Hill (2018), who finds positive spillover effects for stronger players in male team sports, which might be explained by higher fatigue in individuals than in team sports.

Result 2. *There exist negative spillover effects for men and women.*

In columns 5 and 6 we focus on the long shadow (*BestRank*) and find a positive and significant impact, which replicates BM's findings for men. In particular, the stronger player's winning probability increases (decreases) when the rank of the best player in the tournament is worse (better). Albeit column 6 shows no differences between men and women, the coefficient of the interaction of the female dummy with the best rank is negative, already suggesting that the effect size for women tends to be smaller. The separate regressions in the appendix confirm this finding, particularly, the coefficient for men is positive and highly significant, whereas we find no such effect for women (see Appendix C, Tables C1 and C2). Following from that, women do not seem to be affected by the rank of the best player in the tournament, whereas male stronger players are negatively affected. Hence, we confirm Hypothesis 3a for men and reject it for women. The results for men are in line with existing studies that find such a superstar effect, for instance, in golf or chess (see, e.g., Bilen & Matros, 2023; Brown, 2011).²⁴ However, results for women differ from Bilen and Matros (2023), who also find a superstar effect for female chess players. Both studies find that the superstar effect only exists for large skill differences between the superstars' (actual) skills and the skill level in the respective competition. Yet, as there are male- and female-dominant tennis players, this does not explain the gender difference in our setting.²⁵ Instead, women might be less sensitive to potential events at some point and rather react to direct consequences that address the immediate subsequent round.

Result 3. *Men are affected by a long shadow in the tournament, whereas there is no such evidence for women.*

When we include the logarithmic purse of the tournament in specification (7) and the prize money differences (between winning or losing) in specification (8), we replicate BM's findings for men that higher total prize money leads to an increase in the stronger player's winning probability, which is consistent with Hypothesis 3b. Yet, prize money differentials do not seem to be a significant predictor of the stronger player's winning probability in general. Interestingly, separate regressions for men and women reveal gender-specific reactions to monetary incentives. For men, the total prize money in the tournament increases the stronger player's winning probability, but prize money differences between rounds do not seem to be important for them. By contrast, women are hardly affected by the total prize money as indicated by the small and insignificant coefficient, thus, Hypothesis 3b can be rejected for women. Instead, prize money differences have a marginally significant negative impact on the stronger player's winning



probability, suggesting that immediate monetary incentives seem to induce some kind of pressure for female stronger players or motivation for female weaker players. This is in line with previous literature which finds females to choke under pressure (Paserman, 2007) and deviates from Cohen-Zada et al. (2017), who find evidence for choking under pressure (higher stakes) only for men and Gilsdorf and Sukhatme (2008), who find that higher prize money differentials affect the stronger player's winning probability positively. Yet, differently from our approach (prize difference between winner and loser), they consider prize differences between winning the tournament and losing the current match.

Result 4. *Higher total prize money affects the stronger player's winning probability positively for men, whereas prize money differences have a negative effect for female stronger players.*

Taken together, we fully replicate BM's findings for men and additionally find a shadow effect for women, which is of similar size as the one for men. Moreover, we find a negative spillover effect for men as well as women. Interestingly, the results for women deviate with respect to a long shadow and monetary incentives. In particular, a male stronger player seems to be motivated by higher total prize money in the tournament and demotivated by a better potential opponent in the tournament. In contrast, female stronger players do not seem to be affected by such distant tournament effects, instead, our results suggest that they are rather sensitive to immediate effects. Specifically, women only react to monetary incentives that address the current round and are overshadowed by a strong potential opponent only in the immediate subsequent round. Hence, immediate consequences (but not some potential events in later rounds) seem to induce some kind of pressure on women that leads to a decrease in the winning probability of the stronger player.

5.2 | Betting market predictions

Following BM, we consider next whether spillover and shadow effects are incorporated in betting market predictions. In doing so, we replace the dependent variable with the probability that the stronger player as defined by the betting odds wins the match as implied by the betting market. We use the same explanatory variables as before, that is, the rank of the expected future opponent, the number of games played in previous matches, a female dummy, interactions with it for the shadow and spillover effects, and the rank ratio. Moreover, we include separate regressions for men and women. The results are shown in Table 3.

Overall, the betting market incorporates the observed effects quite well. In particular, all specifications show that the betting market correctly anticipates the shadow effect for men and women lending support to Hypothesis 4a. A one standard deviation decrease in the rank of the expected opponent is associated with a 3.4 percentage points lower predicted probability that the stronger player wins the match, which holds for men and women. This effect size is well in line with BM's findings which lie between 1.1 and 3.2 percentage points. Moreover, the spillover effect is correctly incorporated in betting market predictions for men and women: the stronger player's number of previously played games enters the stronger player's winning probability negatively and the number of past games played by the opponent positively. This supports Hypothesis 4b. Interestingly, the betting market also predicts a gender difference with respect to the spillover effect that we do not find significant evidence for. However, the estimates match the direction that we find in our separate regressions, that is, women are less affected by a spillover effect than men. This holds for both, the stronger and the weaker player and is plausible given the best-of-five rule implemented in grand slams for men.

Result 5. *The betting market anticipates shadow and spillover effects for men and women.*

As betting market data can incorporate more up-to-date information, such as temporary bad rankings of actually well-performing players, for instance, due to temporary time-outs or current injuries, that are not reflected in their ranks, it is possible to identify predicted upsets. Investigating those, we can ensure that our results are not driven by unobserved factors that impact the winning probability of the stronger player. In line with BM, we define a predicted upset as follows: The betting market predicts that the weaker player (worse rank) wins (probability larger than 50%) and the player actually wins. There are 1518 predicted upsets in our data set (about 7% of observations), but most of them (1238 cases) only happened once per player and year-specific tournament.²⁶ Hence, a very large share of 99.39%

TABLE 3 Regressions of predicted stronger player's winning probability.

Variables	Dependent variable: Prediction that stronger player wins (0%–100%)				
	(1) All	(2) All	(3) All	(4) Men	(5) Women
<i>Constant</i>	71.40*** (0.504)	71.52*** (0.574)	70.92*** (0.511)	70.90*** (0.684)	63.81*** (0.488)
<i>ExpFutureOppRank</i>	0.130*** (0.0105)	0.125*** (0.0137)	0.128*** (0.0105)	0.134*** (0.0155)	0.114*** (0.0108)
<i>Female</i>	−8.439*** (0.484)	−8.702*** (0.591)	−7.130*** (0.516)		
<i>Female × ExpFutureOppRank</i>		0.00930 (0.0148)			
<i>PastGamesStrong</i>	−0.246*** (0.0213)	−0.247*** (0.0214)	−0.270*** (0.0249)	−0.297*** (0.0268)	−0.165*** (0.0283)
<i>Female × PastGamesStrong</i>			0.0580* (0.0299)		
<i>PastGamesWeak</i>	0.181*** (0.0198)	0.180*** (0.0197)	0.196*** (0.0233)	0.195*** (0.0244)	0.0855*** (0.0282)
<i>Female × PastGamesWeak</i>			−0.115*** (0.0297)		
<i>RankRatio</i>	0.204*** (0.0460)	0.204*** (0.0460)	0.203*** (0.0459)	0.160*** (0.0490)	0.306*** (0.0301)
Round fixed effects	x	x	x	x	x
Tournament-year fixed effects	x	x	x	x	x
<i>Observations</i>	20,294	20,294	20,294	11,526	8768
<i>R</i> ²	0.101	0.101	0.102	0.084	0.111

Note: Robust standard errors clustered on tournament-year level in parentheses.

*** $p < .01$; ** $p < .05$; * $p < .1$.

of observations include either no predicted upset or just one predicted upset per year-specific tournament. We thus conclude that our results are not driven by unobserved factors.

In sum, we find that the shadow and spillover effects are well incorporated in the betting market, which holds for men and women. This result is in line with BM and deviates from Hill (2018), who finds that shadow and positive spillover effects for male teams are not correctly incorporated in the betting market.

5.3 | Uncertainty as potential source of the shadow effect

We next extend BM's study by considering (un)certainly as a possible major source for explaining the shadow effect. Particularly, we study whether the shadow effect is weaker (stronger) when the future opponent is unknown (known) and whether this is gender-specific.

Our data set includes two general cases: The future opponent's rank is known (the parallel match is already finished) and the future opponent's rank is unknown. In the latter case, there are two possibilities, the parallel match is played after the own match or the parallel match is played at the same time and the future opponent's rank is only known at some point during the own match. In both situations, the future opponent's rank is unknown at the beginning of the match, that is, players can only form expectations.



We run ordinary least squares regressions of the stronger player's winning probability as specified before and account for different states of information as well as gender.²⁷ In specifications (1) and (2) we only consider matches with unknown future opponents. The explanatory variables are again the rank of the expected future opponent, a player's own and the opponent's number of games played in previous matches and the rank ratio. In specification (2) we additionally consider whether a match is played at the same time or only when the own match is finished (*Plays*; $1 = \text{plays at the same time}$) and its interaction with the expected future opponent's rank. In specification (3), we focus on parallel matches that are already finished, thus, the expected future opponent's rank is replaced by the future rank of the opponent (*FutureOppRank*) as it is known for sure. Finally, in specification (4) we consider the pooled data and use (*Exp*)*FutureOppRank* that equals the expected future opponent's rank for unknown opponents and the future rank for known opponents as well as the interaction with *Known* ($1 = \text{opponent is known}$). The regression results are shown in Table 4.

TABLE 4 Regressions of stronger player's winning probability (separated by state of information and gender).

Variables	Dependent variable: Stronger player wins (0% or 100%)							
	Men				Women			
	(1a) Unknown	(2a) Unknown	(3a) Known	(4a) All	(1b) Unknown	(2b) Unknown	(3b) Known	(4b) All
<i>Constant</i>	61.66*** (1.273)	60.58*** (1.867)	66.33*** (1.856)	62.67*** (1.078)	56.01*** (1.144)	57.85*** (1.706)	70.62*** (2.155)	58.64*** (1.018)
<i>ExpFutureOppRank</i>	0.209*** (0.0260)	0.278*** (0.0550)			0.197*** (0.0247)	0.155*** (0.0406)		
<i>Plays</i>		1.433 (1.7076)				−2.800 (1.9468)		
<i>Plays × ExpFutureOppRank</i>		−0.0841 (0.0521)				0.0638 (0.0487)		
<i>FutureOppRank</i>			0.0805*** (0.0184)				0.0440 (0.0268)	
<i>(Exp)FutureOppRank</i>				0.199*** (0.0244)				0.188*** (0.0243)
<i>Known</i>				2.133* (1.224)				4.113*** (1.513)
<i>Known × (Exp)FutureOppRank</i>				−0.105*** (0.0293)				−0.136*** (0.0332)
<i>PastGamesStrong</i>	−0.325*** (0.0522)	−0.329*** (0.0525)	−0.297*** (0.0718)	−0.317*** (0.0421)	−0.239*** (0.0754)	−0.243*** (0.0757)	−0.456*** (0.0926)	−0.301*** (0.0582)
<i>PastGamesWeak</i>	0.253*** (0.0494)	0.250*** (0.0493)	0.240*** (0.0647)	0.253*** (0.0394)	0.182** (0.0811)	0.184** (0.0811)	0.267*** (0.101)	0.217*** (0.0663)
<i>RankRatio</i>	0.158*** (0.0602)	0.156*** (0.0596)	0.321*** (0.0492)	0.187*** (0.0611)	0.343*** (0.0419)	0.343*** (0.0421)	0.341*** (0.0389)	0.344*** (0.0326)
Round fixed effects	x	x	x	x	x	x	x	x
Tournament-year fixed effects	x	x	x	x	x	x	x	x
<i>Observations</i>	7275	7275	4232	11,507	5793	5793	2952	8745
<i>R</i> ²	0.059	0.059	0.084	0.058	0.050	0.050	0.060	0.044

Note: Robust standard errors clustered on tournament-year level in parentheses.

*** $p < .01$; ** $p < .05$; * $p < .1$.

The regression results reveal a shadow effect for men and women in case their future opponent is unknown. Hence, if players need to build expectations about the rank of the future opponent, they are overshadowed by losing more often, even though being the stronger player. These results support Hypothesis 5b. Investigating further whether imprecise information due to the parallel match being played at the same time can reduce or even eliminate the shadow effect, is considered in specification (2). However, the results do not support this idea. If the information about the rank of the future opponent is not known at the beginning of the match, but is only available during its course, a shadow effect exists for both, men and women.

In contrast, in case the future opponent's rank is known (columns 3a and 3b), we find different reactions for men and women. While male stronger players suffer from a shadow effect, female stronger players do not. Hence, men's behavior is consistent with Hypothesis 5a, whereas women's behavior is not.

In specification (4) we confirm the findings from the regressions separated by the state of information and moreover consider the effect sizes of the shadow effect. For both, men and women, the coefficient of the expected future opponent's rank is positive and significant, whereas the interaction with *Known* is negative and significant, meaning that the shadow effect is lower in case the future opponent is known. These results contradict Hypothesis 5c. Moreover, albeit there is a discount on the shadow effect for men and women when the future opponent is known, the discount is stronger for women which is consistent with the findings from the disaggregated specifications. Overall, the results indicate that uncertainty is a strong driver of the shadow effect. Moreover, men and women seem to prefer certain situations, which is more pronounced for women. In fact, in case they know their future opponent, the shadow effect even seems to vanish.

Result 6. *Certainty about the future opponent's ability can reduce the shadow effect for men and eliminate it for women.*

Although it is in contrast to our theoretical predictions, this finding is well in line with previous literature, particularly, that women strongly react to information (e.g., Gee, 2019; Wozniak, 2012) and can even be encouraged to enter competitions when uncertainty is eliminated (Ertac & Szentes, 2011). Moreover, the effects for men are consistent with the results of Hill (2018), who finds a shadow effect for known future opponents.

Finally, the regression results show that stronger players are negatively affected by a spillover effect, irrespective of whether the future opponent is known or not, which is consistent with Hypothesis 5d. Moreover, when the weaker player has played more games in previous rounds, the winning probability of the stronger player in the current round increases. These results hold for both, men and women.

Result 7. *Men and women are affected by a negative spillover effect under both, certainty and uncertainty.*

To sum up, the shadow effect for men is lower in case of certainty about future opponents, whereas the shadow effect for women seems to be completely driven by uncertainty, which has important policy implications. If the ability of the future competitor is known, this information should be made available as it increases the performance of the more capable individual. Especially highly qualified women might benefit from this information. For instance, they could receive information about the promotion of a particular individual in another subdivision who will potentially be a rival in the future because both aim for the lead of the division. Furthermore, the results might be applied in the context of internal versus external firm hires. For example, information about potential competitors in the next round might be available for candidates in the case of within-firm hires, but is most likely not available in the case of external hires. Hence, candidates have some knowledge about their potential competitors in the first case, whereas they need to form expectations in the latter case. Eventually, our results suggest that individuals only benefit from the information if they have enough time to react.

5.4 | Surprise victories as specific source of information

Next, we focus in more detail on information about the skill level of future opponents. In particular, we further separate the effect of surprise victories, that is, whether the stronger or weaker player (defined by ranks) won a particular match. This complements our analyses about the impact of a specific rank on the future opponent as a player's motivation might be moderated by the knowledge about whether the stronger or weaker player won the

parallel match. We define a surprise victory in the parallel match as a victory (defeat) of the weaker (stronger) player according to their ranking. In our data set, about 26.55% of matches are won by the weaker player according to this definition. To account for predicted upsets, that is, potentially “wrongly” determined stronger player players based on their ranks, we further consider the future opponent to be a surprise if the stronger player as predicted by the betting market loses the parallel match. This is the case in about 21.24% of observations. Eventually, we are interested in whether a known surprise victory in the parallel match impacts the winning probability of the stronger player.

To shed light on this question, we run additional regressions of the winning probability for known future opponents that are similar to above, but additionally include a dummy variable that indicates whether the weaker player won the parallel match (*SurpriseOpp*; 1 = weaker player won) in specification (1) as well as an interaction with the future opponent's rank in specification (2). The last two specifications (3) and (4) replace the surprise dummy with a surprise dummy based on betting market data that indicates whether the player that was predicted to win actually won the match (*SurpriseOppBet*, 1 = winner was predicted to lose the match). The results are shown in Table 5.

In line with our previous findings, the winning probability of male stronger players decreases when the known future opponent is stronger, whereas there is no such significant effect for women. Surprise victories have no general effect on the stronger player's winning probability, neither for men nor for women. We thus reject Hypothesis 6. Overall, it does not seem to matter whether the stronger or weaker player is the future opponent. Again, this result

TABLE 5 Regressions of stronger player's winning probability accounting for surprise victories.

Variables	Dependent variable: Stronger player wins (0% or 100%)							
	Men				Women			
	(1a)	(2a)	(3a)	(4a)	(1b)	(2b)	(3b)	(4b)
Constant	66.29*** (1.850)	66.06*** (2.108)	66.26*** (1.863)	65.78*** (2.037)	70.60*** (2.135)	68.92*** (2.679)	70.64*** (2.137)	71.31*** (2.421)
FutureOppRank	0.0800*** (0.0208)	0.0899** (0.0438)	0.0888*** (0.0195)	0.101*** (0.0270)	0.0397 (0.0311)	0.0948 (0.0594)	0.0447 (0.0289)	0.0276 (0.0366)
SurpriseOpp	0.104 (2.066)	0.536 (2.435)			0.860 (2.511)	2.919 (3.447)		
SurpriseOpp × FutureOppRank		−0.0138 (0.0419)				−0.0655 (0.0625)		
SurpriseOppBet			−2.635 (2.647)	−1.105 (3.168)			−0.261 (2.364)	−2.951 (3.854)
SurpriseOppBet × FutureOppRank				−0.0310 (0.0311)				0.0490 (0.0520)
PastGamesStrong	−0.294*** (0.0713)	−0.293*** (0.0711)	−0.294*** (0.0713)	−0.293*** (0.0713)	−0.460*** (0.0947)	−0.455*** (0.0941)	−0.462*** (0.0944)	−0.465*** (0.0948)
PastGamesWeak	0.238*** (0.0643)	0.239*** (0.0644)	0.239*** (0.0644)	0.240*** (0.0643)	0.272*** (0.102)	0.276*** (0.102)	0.272*** (0.102)	0.273*** (0.102)
RankRatio	0.322*** (0.0492)	0.321*** (0.0496)	0.321*** (0.0488)	0.318*** (0.0488)	0.341*** (0.0389)	0.331*** (0.0402)	0.341*** (0.0388)	0.346*** (0.0394)
Round fixed effects	x	x	x	x	x	x	x	x
Tournament-year fixed effects	x	x	x	x	x	x	x	x
Observations	4232	4232	4232	4232	2951	2951	2951	2951
R ²	0.084	0.084	0.084	0.084	0.060	0.061	0.060	0.061

Note: The sample is restricted to matches with known future opponents. Robust standard errors clustered on tournament-year level in parentheses.

*** $p < .01$; ** $p < .05$; * $p < .1$.

deviates from the findings for male basketball teams whose winning probability is higher in case of a surprise victory, that is, when the future opponent is weaker than expected (see Hill, 2018).

Corroborating our previous findings, defining a surprise victory based on betting market data (columns 3 and 4) yields no significant estimate for the coefficient of *SurpriseOppBet* and also its interaction term with the rank of the future opponent is not significantly different from zero.

Result 8. *Knowing about a surprise victory in the parallel match does not seem to affect the stronger player's winning probability.*

In sum, whether or not the stronger or weaker player wins the parallel match does not affect the winning probability of the stronger player and does not seem to play a crucial role in promoting highly qualified individuals. Instead, the exact strength of the future opponent seems to be a driving force for a male stronger player's winning probability, whereas knowing the exact strength of the opponent seems to be less important for female stronger players.

6 | CONCLUSION

In strategic environments, individuals' expectations about the future impact current decisions and behavior in general. In the case of multistage competitions, it has already been shown that the winning probability of male favorites tends to decrease when a strong future opponent is expected. Yet, it is unclear so far, whether this effect also exists for women and whether it is linked to the degree of information precision. Moreover, it is well known that there exist many gender differences, for example, with respect to their decision-making and optimism (e.g., Patton et al., 2004). Such evidence helps explain differences in (labor) market outcomes and might lend guidance for implementing an environment that promotes gender equality.

We complement previous research by focusing on how women who have already entered a competition incorporate future competition into their current behavior. In particular, we first tie up to Brown and Minor (2014) and replicate their analysis for men and women. Specifically, we investigate how men's and women's current winning probabilities in professional tennis depend on the strength of the expected future opponent and their effort in previous rounds. Importantly, we extend the analysis by including the degree of foreseeability, that is, whether players expect a specific opponent or they know their future opponent for sure. Moreover, we investigate known surprise victories, particularly, when it is known that the weaker player won the parallel match and is hence the future opponent in the next round.

Our results in the first part of our analysis suggest that the favorite's winning probability is lower when the expected opponent is stronger, thus, there exists a shadow effect for men and women, which seems to be of similar size. Moreover, we find negative spillover effects for men as well as women. Both, shadow as well as spillover effects for men and women, are already incorporated in the betting market. These results are in line with BM's findings for men. Interestingly, our results reveal a gender difference with respect to the long shadow. In particular, when the rank of the best player in a tournament is better, the favorite's winning probability decreases for men, which is again in line with BM. However, we do not find such a long shadow for women. In line with this finding, distant monetary incentives, in the form of total prize money positively impact the male favorite's winning probability which is in line with BM. However, we do not find such an effect on women. In contrast, immediate monetary incentives in terms of prize money differences (between winner and loser), tend to decrease female favorite's winning probability, but not for men. Taken together, women rather seem to be affected by immediate effects whereas men are sensitive to distant consequences.

Remarkably, in the second part of our analysis we uncover gender differences when it comes to the role of uncertainty. It turns out that knowing the future opponent is the driving force behind the shadow effect for women. In particular, we find no shadow effect when the future opponent is already known before the start of a match. Results for men deviate from this finding, particularly, the shadow effect also becomes smaller when knowing the future opponent's rank, but is still existent. Plausibly, the spillover effect is not affected by uncertainty. As men and women are similarly negatively affected by matches in previous rounds, both seem to need some time to recover to retrieve their best performance. Finally, knowing that the future opponent already defeated a favorite in the current round, does not impact the own winning probability for men and women.

The most important implication of our finding refers to information revelation. We find that a woman is not overshadowed by future competition in case she knows who she is up against and also men suffer less from the shadow effect when uncertainty is eliminated. Thus, information about future competitors should be revealed to identify the

highest qualified individual. This is important, for instance, in the job market for application processes and within-firm promotions. Eventually, revealing information can especially be helpful to promote capable women to climb the career ladder.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon request.

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ENDNOTES

- ¹ For a review, see Blau and Kahn (2017).
- ² For an overview on gender differences in preferences see Croson and Gneezy (2009) and Bertrand (2011).
- ³ Ryvkin (2011) experimentally finds that subjects seem to be unaware of the negative effect of fatigue. Yet, we suspect that this is not the case in professional sports as it is well known that physical fatigue decreases performance.
- ⁴ Even ex ante homogeneous tennis matches are likely to end in two rounds because the player who wins the first set is more likely to win the second set. In case of a third set, both players are equally likely to win (Malueg & Yates, 2010).
- ⁵ The data that support the findings of this study are available from the corresponding author upon request.
- ⁶ In contrast, Ely et al. (2017) find that women, as well as men, adapt their strategies (for serves) in an optimal way with respect to risk-return trade-offs.
- ⁷ Accessed in August 2019 for women's grand slams, in March 2020 for PM WTA and in February 2021 for men's data. The respective tournaments in ATP1000 are: Rogers Cup (Canada Masters), Western and Southern Open (Cincinnati), Hamburg European Open (2008 only), BNP Paribas Open (Indian Wells), Mutua Madrid Open, Miami Open, Monte Carlo Rolex Masters, Rolex Paris Masters, Internazionali BNL d'Italia (Rome), Shanghai Rolex Masters (since 2009) and in PM WTA: BNP Paribas Open (Indian Wells), Mutua Madrid Open, Miami Open, China Open (Beijing).
- ⁸ Grand slams, BNP Paribas Open, and Miami Open are played over seven rounds, all other draws consist of six rounds.
- ⁹ In some ATP1000 and PM WTA tournaments, the first rounds include byes, hence, the number of matches and players is lower.
- ¹⁰ Information about prize money is collected from <http://www.perfect-tennis.com> and additional sources that are listed in Appendix A (see Tables A1 and A2). We converted the prize money to 2019 USD using the CPI conversion factor provided by the US Bureau of Labour Statistics: http://www.bls.gov/data/inflation_calculator.htm (accessed in April 2020).
- ¹¹ Points for the world ranking vary across event and round (see Appendix A, Table A3), but are comparable for men and women. Players only receive points for the highest round reached. World rankings are updated in weekly intervals.
- ¹² As shown by BM in a simulation study, the seeding does not impact the results. We rely on these findings in our further analyses and further ensure robustness by running additional regressions excluding the top four seeds. The regressions yield qualitatively the same results and are available upon request.
- ¹³ Data on match duration is often directly available (data sets *tennis_atp* and *tennis_wta*). If data are not available for grand slam matches, we compute the duration as the difference in starting time and last point played (data set *tennis_slam_pointbypoint*). We accessed women's data in March and April 2020 and men's data in February 2021.
- ¹⁴ In our sample, the median match duration for best-of-five matches is 139 min and more than 75% are shorter than 178 min. For best-of-three matches, median match duration is 94 (88) min for men (women), and more than 75% of matches are shorter than 122 (117) min.
- ¹⁵ As our data set only includes six- and seven-round tournaments, we compare our estimates to those results in BM.
- ¹⁶ We use betting market data from bet365 that covers more than 99% of observations in our data set. The information is included in the data from <http://www.tennis-data.co.uk>.
- ¹⁷ In this context, a better (worse) rank equals a lower (higher) numerical value, that is, the best player holds rank 1, the second best player holds rank 2, and so forth.
- ¹⁸ For a theoretical derivation of the hypotheses on the basis of BM's model see Appendix B.

- ¹⁹ The number of previously played games is computed by aggregation over all previous matches. For the first round, the variables *PastGamesStrong_{mrt}* and *PastGamesWeak_{mrt}* are set to zero.
- ²⁰ As we do not have five-round tournaments in our data set and most tournaments are played over seven rounds (75% of observations) we do not show the results split up by the number of rounds. Separate regressions for grand slams or controlling for the number of rounds yield qualitatively the same results and are available upon request.
- ²¹ The tournaments are played on different surfaces: carpet, clay, grass, hard, and either inside or outside.
- ²² If not indicated otherwise, results are qualitatively the same and included in Appendix C, Tables C1 and C2. Moreover, results are robust to including individual player fixed effects (the regressions are available upon request).
- ²³ In the regressions disaggregated by gender, we further find a negative spillover effect on set level only for male players, that is, having played one set more in the previous round results in a lower winning probability of the stronger player (available upon request).
- ²⁴ Brown (2011) finds that the presence of Tiger Woods leads to a lower performance of others, whereas Bilen and Matros (2023) consider multiple chess superstars from different time periods.
- ²⁵ There are three dominant male players (first rank is occupied in 39.6% by N. Djokovic (wins 88% of matches), 32.7% R. Nadal (87% wins), 15.1% R. Federer (85% wins), all others <10%), whereas there is one dominant female player (first rank is occupied in 44.0% by S. Williams (90% wins), all others <10%).
- ²⁶ In 110 cases, two predicted upsets occurred within a tournament, and in nine cases, three player-specific predicted upsets happened within a tournament. We observe four and five predicted upsets in three cases each, and six predicted upsets within a tournament for one player.
- ²⁷ To avoid multiple interactions, we show separate regressions for men and women. Regressions with pooled data are included in the appendix and yield qualitatively the same results.
- ²⁸ Our analysis will reveal that there are no systematic gender differences that might be explained by variations in factors a and c_i within the model.
- ²⁹ Knowing the future opponent is analog to expecting $p_{1li} = 0$ (or $p_{1li} = 1$).
- ³⁰ The hypotheses are numbered according to Section 4.

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APPENDIX A: MONETARY AND NONMONETARY REWARDS

See Tables A1–A3.

TABLE A1 Round-specific prize money references.

Tournament	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Australian Open	–	TS	TG	PT	PT	PT	PT	PT	PT	PT	PT
French Open	–	–	–	PT	PT	PT	TG	PT	PT	PT	PT
US Open	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT
Wimbledon	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT
<i>ATP1000 Tour</i>											
BNP Paribas Open	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT
Western and Southern Open	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT
Rogers Cup	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT
Miami Open	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT
Monte Carlo Rolex Masters	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT
Mutua Madrid Open	–	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT
Rolex Paris Masters	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT
Internazionali BNL d'Italia	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT
Hamburg European Open	PT	–	–	–	–	–	–	–	–	–	–
Shanghai Rolex Masters	–	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT
<i>PM WTA Tour</i>											
BNP Paribas Open	WTA1	WTA1	WTA1	WTA1	WTA1	WTA1	WTA1	WTA1	WTA1	WTA1	WTA4
China Open	–	WTA3	WTA3	WTA3	WTA3	WTA3	WTA3	WTA3	WTA3	WTA2	WTA3
Miami Open	WTA1	WTA2	WTA2	WTA3	WTA3	WTA3	WTA3	TG	WTA2	WTA2	WTA2
Mutua Madrid Open	–	MO	MO	MO	MO	MO	MO	MO	MO	MO	PT

Note: The abbreviations denote the following sources:

(MO) <https://www.madrid-open.com/>, (TS) <http://tennis.sporting99.com/>, (TG) <http://www.tennisguru.net/>, (PT) <https://www.perfect-tennis.com/>, (WTA1) <https://wtafiles.blob.core.windows.net/>, (WTA2) <http://wtafiles.wtatennis.com/>, (WTA3) <http://wtafiles.wtatennis.com/>, (WTA4) <http://11f4k830or6yrwagw43qiccz-wpengine.netdna-ssl.com>, and (–) denotes missing data.

All sources were accessed in April 2020 for women's data and complemented with men's data in March 2021.

TABLE A2 Tournaments' total purse references.

Tournament	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Australian Open	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT
French Open	–	–	–	PT	PT	PT	PT	PT	PT	PT	PT
US Open	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT
Wimbledon	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT
<i>ATP1000 Tour</i>											
BNP Paribas Open	–	–	–	–	PT	PT	PT	PT	PT	PT	PT
Western and Southern Open	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT
Rogers Cup	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT
Miami Open	–	–	–	–	–	–	PT	PT	PT	PT	PT
Monte Carlo Rolex Masters	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT
Mutua Madrid Open	–	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT
Rolux Paris Masters	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT
Internazionali BNL d'Itali	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT
Hamburg European Open	PT	–	–	–	–	–	–	–	–	–	–
Shanghai Rolex Masters	–	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT
<i>PM WTA Tour</i>											
BNP Paribas Open	WTA1	WTA1	WTA1	WTA1	PT	PT	PT	PT	PT	PT	PT
China Open	–	WTA3	WTA3	WTA3	WTA3	WTA3	WTA3	WTA3	WTA3	WTA2	WTA3
Miami Open	WTA1	WTA2	WTA2	WTA3	WTA3	WTA3	PT	PT	PT	PT	PT
Mutua Madrid Open	–	PT	PT	PT	PT	PT	PT	PT	PT	PT	PT

Note: The abbreviations denote the following sources:

(PT) <https://www.perfect-tennis.com/>, (WTA1) <https://wtatennis.com/news/1312140/rankings>, (WTA2) <http://wtatennis.com/>, (WTA3) <http://wtatennis.com/>, and (–) denotes missing data. All sources were accessed in March 2021.

TABLE A3 Points for the world ranking.

Round	Grand slams	PM WTA Tour	ATP1000 Tour
Winning the final	2000	1000	1000
Playing the final	1300	650	600
Winning the semifinal	780	390	360
Winning the quarterfinal	430	215	180
Winning the 4th round	240	120	90
Winning the 3rd round	130	65	45
Winning the 2nd round	70	35	25
Winning the 1st round	10	10	10

Note: Information is taken from <https://www.wtatennis.com/news/1312140/rankings>, accessed in May 2020.

APPENDIX B: MODEL FOR THEORETICAL DERIVATION OF HYPOTHESES

The following model is extracted from BM, who do not focus on the impact of uncertainty, that is, whether the future opponent is known or players have to form expectations about her. As we are interested in the interplay of uncertainty and the shadow effect, we focus on the role of uncertainty in their model.

There are four players i that compete in two rounds, the first round and the final. Without loss of generality, players 3 and 4 compete against each other in the first round (first match). Afterwards, players 1 and 2 play against each other (second match). Hence, players 3 and 4 need to form expectations about their future opponent, whereas players 1 and 2 know their future opponent before starting their match.

The winner of the final wins V_W and the loser wins V_L , with $V_W > V_L > 0$. The prize spread is denoted as $\Delta V = V_W - V_L$. Losers of the first round receive no prize. It is furthermore assumed that all players are risk neutral and there is no discounting across stages.

To win a match, players need to produce a higher output than their opponent. The output depends on both, their chosen effort level x_i and a random factor ε_i , that is, the output equals $x_i + \varepsilon_i$. Providing effort level x_i is associated with total costs of $\frac{1}{2}c_i x_i$, where c_i denotes the cost type of player i . Cost types are common knowledge and stronger players have lower costs to provide effort level x_i , particularly, we assume $c_1 < c_2 < c_3 < c_4$, with $c_i > 0$.

The probability of player i to win against player j given that they provide effort levels x_i and x_j , respectively, is denoted as $P_i(x_i, x_j)$. The difference in random factors, $\varepsilon = \varepsilon_j - \varepsilon_i$, follows a uniform distribution $G \sim U\left[-\frac{1}{2}a, \frac{1}{2}a\right]$, such that, $G' = \frac{1}{a}$ and $P_i(x_i, x_j) = G(x_i - x_j)$. It might be that factors in the model are gender-specific. Especially, men and women might differ in terms of their cost types c_i (e.g., homogeneity of player skills), and their distributions of random factors a (e.g., due to confidence of winning, perception of spectator support, and impact of mood). In our data set, female favorites win less often than their male counterparts which corresponds to more homogeneous cost types or a wider distribution of random factors for females. In line with the setup of tennis matches, we derive the hypotheses for within-gender tournaments and analyze potential gender differences on an explorative basis.²⁸

Under these assumptions, player i 's expected payoff in the final equals

$$\pi_{i,final} = P_i(x_i, x_j)\Delta V - \frac{1}{2}c_i x_i^2 + V_L.$$

Solving the payoff maximizing first-order condition for the final yields the optimal effort levels for players i and j , respectively,

$$x_i^* = \frac{\Delta V}{ac_i}, \quad x_j^* = \frac{\Delta V}{ac_j}.$$

Hence, effort levels do not depend on the opponent's effort level in a given match, but only on the player-specific cost type and the prize spread. Due to the convex cost function, individuals always exert positive effort.

We next consider the first round, that is, the first match (player 3 against player 4) and the second match (player 1 against player 2). Denoting the effort provided in the first round as z_i , we can express player 1's first-round expected payoff as

$$\pi_{1,first} = P_1(z_1, z_2)\tilde{V}_1 - \frac{1}{2}c_1 z_1^2,$$

where \tilde{V}_1 is the payoff of player 1 in the final, that is, $\tilde{V}_1 = \pi_{1,final}$ (analogously for player 2).

In contrast, players 3 and 4 do not know their opponent in the final and therefore need to form expectations about the final. In particular, player 3's expected payoff in the first round equals

$$\pi_{3,first} = P_3(z_3, z_4)E[\tilde{V}_3] - \frac{1}{2}c_3 z_3^2,$$

where player 3's expected payoff in the final includes her expectations about the probability that player 1 wins against player 2 given that player 1 knows that her future opponent is player 3 (analogously for player 4). This is denoted as $p_{1|3}$ (more generally: $p_{1|i}$, $i \in \{3, 4\}$) and cannot be influenced by player 3 (resp., player 4). The expected payoff of player 3 (resp., player 4) in the final is hence the expected payoff multiplied by the probabilities that she plays against player 1 or player 2:



$$E[\tilde{V}_i] = p_{1li} \tilde{V}_i(x_i^*, x_1^*) + (1 - p_{1li}) \tilde{V}_i(x_i^*, x_2^*).$$

Player 3's expected payoff in the first round is thus (analogously for player 4)

$$\begin{aligned} \pi_{3,first} &= P_3(z_3, z_4) E[\tilde{V}_3] - \frac{1}{2} c_3 z_3^2 \\ &= P_3(z_3, z_4) \left(p_{1l3} \tilde{V}_3(x_3^*, x_1^*) + (1 - p_{1l3}) \tilde{V}_3(x_3^*, x_2^*) \right) - \frac{1}{2} c_3 z_3^2. \end{aligned}$$

Solving for the optimal effort levels of all players in the first round yields

$$\begin{aligned} z_1^* &= \frac{\tilde{V}_1}{ac_1}, & z_2^* &= \frac{\tilde{V}_2}{ac_2}, \\ z_3^* &= \frac{E[\tilde{V}_3]}{ac_3}, & z_4^* &= \frac{E[\tilde{V}_4]}{ac_4}. \end{aligned}$$

Assuming that $c_1 < c_2$ and $p_{1li} \in (0, 1)$, it follows that $\tilde{V}_3(x_3^*, x_1^*) < E[\tilde{V}_3] < \tilde{V}_3(x_3^*, x_2^*)$. Particularly, player 3's expected payoff in the final is larger in case she does not know her future opponent than in case she knows she will play against player 1 and lower than in case she knows that she will play against player 2.²⁹ Hence, the effort level in the first round depends on her expectations about the future opponent. If she believes that there is some positive likelihood to play against player 2, she will exert more effort than if she knew that she will play against player 1.

Shadow effect

We now consider the impact of an increase in strength (decrease in costs) of the future opponent on the effort level in the first round. In particular, we investigate whether the stronger players in each match, that is, player 1, who knows her future opponent, or player 3, who forms expectations about her, will decrease her effort more if the (expected) future opponent is stronger.

We start with an estimation of the shadow effect in case the future opponent is known, that is, we compare whether the stronger or weaker player decreases her effort more when the future opponent is stronger. Assuming that player 3 won the parallel match, we consider $\frac{\partial z_1^*}{\partial c_3}$ and $\frac{\partial z_2^*}{\partial c_3}$ (analogously if player 4 won the parallel match). On the basis of BM's model we observe that the stronger player decreases effort more than the weaker player, particularly,

$$\frac{\partial z_1^*}{\partial c_3} = \frac{(\Delta V)^2}{a^3 c_1 c_3^2} > \frac{\partial z_2^*}{\partial c_3} = \frac{(\Delta V)^2}{a^3 c_2 c_3^2}.$$

Therefore we state the following hypothesis³⁰:

Hypothesis 5a. The stronger player's winning probability decreases when the known future opponent's rank is better. This holds for men and women.

Analogously, we consider the case for unknown future opponents, that is, whether player 3 or player 4 decreases her effort more when the expected future opponent is stronger which corresponds to a decrease in player 1's effort costs (analogously a decrease in player 2's effort costs), whereby

$$\begin{aligned} z_i^* &= \frac{E[\tilde{V}_i]}{ac_i} = \frac{1}{ac_i} \left(p_{1li} \tilde{V}_i(x_i^*, x_1^*) + (1 - p_{1li}) \tilde{V}_i(x_i^*, x_2^*) \right) \\ &= \frac{1}{ac_i} \left[p_{1li} \left(G(x_i^* - x_1^*) \Delta V - \frac{1}{2} c_i x_i^2 + V_L \right) + (1 - p_{1li}) \left(G(x_i^* - x_2^*) \Delta V - \frac{1}{2} c_i x_i^2 + V_L \right) \right] \\ &= \frac{1}{ac_i} \left[p_{1li} \left(\frac{\frac{\Delta V}{ac_i} - \frac{\Delta V}{ac_1} + \frac{1}{2} a}{a} \Delta V - \frac{1}{2} c_i x_i^2 + V_L \right) + (1 - p_{1li}) \left(\frac{\frac{\Delta V}{ac_i} - \frac{\Delta V}{ac_2} + \frac{1}{2} a}{a} \Delta V - \frac{1}{2} c_i x_i^2 + V_L \right) \right], \\ \frac{\partial z_i^*}{\partial c_1} &= \frac{1}{ac_i} \left[p_{1li} \frac{\Delta V}{a^2 c_1^2} \Delta V \right] = p_{1li} \frac{(\Delta V)^2}{a^3 c_1^2 c_i} > 0. \end{aligned}$$

Hence the stronger player 3 is more affected by the shadow effect if $\frac{p_{113}}{p_{114}} > \frac{c_3}{c_4}$. In other words, the ability difference between players 3 and 4 must be larger than the shadow effect that is initiated by these differences, that is, the shadow effect for player 1 given that she knows she will play against the stronger player relative to knowing she will play against the weaker player. As we assume this condition to hold, the shadow effects for players 3 and 4 are

$$\frac{\partial z_3^*}{\partial c_1} = p_{113} \frac{(\Delta V)^2}{a^3 c_1^2 c_3} > \frac{\partial z_4^*}{\partial c_1} = p_{114} \frac{(\Delta V)^2}{a^3 c_1^2 c_4}.$$

Hence, the stronger player's winning probability is lower when the expected future opponent is stronger as she reduces her effort more than the weaker player. We thus state our next hypothesis:

Hypothesis 5b. The stronger player's winning probability decreases when the expected future opponent's rank is better. This holds for men and women.

When looking at the interplay of uncertainty and the shadow effect, we compare the shadow effects of players 1 and 3 (the stronger players in each match), $\frac{\partial z_1^*}{\partial c_3}$ and $\frac{\partial z_3^*}{\partial c_1}$. This reveals that uncertainty about the future opponent decreases the effect size of the shadow effect by the factor p_{113} . In particular, if players 1 and 3 had the same effort costs $c_1 = c_3 = \tilde{c}$, it yields

$$\frac{\partial \tilde{z}_1^*}{\partial \tilde{c}} = \frac{(\Delta V)^2}{a^3 \tilde{c}^3} > \frac{\partial \tilde{z}_3^*}{\partial \tilde{c}} = p_{113} \frac{(\Delta V)^2}{a^3 \tilde{c}^3}.$$

Hence, the stronger player decreases her effort less if she does not know her future opponent in contrast to knowing the future opponent, meaning that the shadow effect is weaker under uncertainty. We therefore state our next hypothesis:

Hypothesis 5c. The stronger player's winning probability decreases more when the future opponent's rank is better and known. This holds for men and women.

Spillover effect

Following BM, a spillover effect is introduced next. In particular, k denotes the change in total costs that is induced in the final due to the effort provided in the first round. In tennis matches, a negative spillover effect due to fatigue is plausible, yet, positive as well as negative spillover effects are possible in the model ($k > 1$ and $k < 1$, respectively). The expected payoff of player i in the final match against player j does not depend on whether players knew their competitor in the previous round and can be expressed as

$$\pi_{i,final} = G(x_i - x_j) \Delta V - \frac{1}{2} k c_i x_i^2 + V_L.$$

Solving the payoff maximizing first-order condition yields

$$x_i^* = \frac{\Delta V}{a k c_i}, \quad x_j^* = \frac{\Delta V}{a k c_j}.$$

Hence, the effort of both players decreases (increases) if a negative (positive) spillover effect is present. However, the spillover effect is not affected by whether the player knows her future opponent or needs to form expectations about her. We thus state our next hypothesis:

Hypothesis 5d. The stronger player's winning probability decreases with the number of previously played games, independently of (not) knowing the future opponent. This holds for men and women.



Shadow and spillover effect

Finally, we consider the combination of shadow and spillover effect, which however does not change our theoretical predictions stated above.

As the spillover effect depends on the effort level provided in the first round, k is a function of z_i , that is, $k(z_i)$. For better reading, we denote $k(z_i)$ as k_i and assume that players 1 and 3 win the first round (analogously for players 2 and 4). Players 1 and 3's efforts in the final are thus

$$x_1^* = \frac{\Delta V}{ak_1 c_1}, \quad x_3^* = \frac{\Delta V}{ak_3 c_3}.$$

In the first round, players 1 and 3 already incorporate the anticipated spillover effect for the final and maximize their expected payoff accordingly. For player 1 it yields

$$\begin{aligned} \pi_{1,first} &= P_1(z_1, z_2) \tilde{V}_1 - \frac{1}{2} c_1 z_1^2 \\ &= P_1(z_1, z_2) \left[G(x_1 - x_3) \Delta V - \frac{1}{2} k_1 c_1 x_1^2 + V_L \right] - \frac{1}{2} c_1 z_1^2 \\ &= P_1(z_1, z_2) \left[\frac{1}{a} \left(\frac{\Delta V}{ak_1 c_1} - \frac{\Delta V}{ak_3 c_3} + \frac{a}{2} \right) \Delta V - \frac{1}{2} k_1 c_1 \left(\frac{\Delta V}{ak_1 c_1} \right)^2 + V_L \right] - \frac{1}{2} c_1 z_1^2 \\ &= P_1(z_1, z_2) \left[\frac{1}{2} \frac{(\Delta V)^2}{a^2 k_1 c_1} - \frac{(\Delta V)^2}{a^2 k_3 c_3} + \frac{1}{2} \Delta V + V_L \right] - \frac{1}{2} c_1 z_1^2. \end{aligned}$$

The expected payoff of player 3 is a weighted average of the payoffs she expects to win when (i) player 1 wins against player 2 or (ii) player 1 loses against player 2, that is,

$$\begin{aligned} \pi_{3,first} &= P_3(z_3, z_4) E[\tilde{V}_3] - \frac{1}{2} c_3 z_3^2 \\ &= P_3(z_3, z_4) \left[p_{113} \tilde{V}_3(x_3^*, x_1^*) + (1 - p_{113}) \tilde{V}_3(x_3^*, x_2^*) \right] - \frac{1}{2} c_3 z_3^2 \\ &= P_3(z_3, z_4) \left[p_{113} \left(G(x_3^* - x_1^*) \Delta V - \frac{1}{2} k_3 c_3 x_3^{*2} + V_L \right) + (1 - p_{113}) \left(G(x_3^* - x_2^*) \Delta V - \frac{1}{2} k_3 c_3 x_3^{*2} + V_L \right) \right] \\ &\quad - \frac{1}{2} c_3 z_3^2 \\ &= P_3(z_3, z_4) \left[p_{113} \left(-\frac{(\Delta V)^2}{a^2 k_1 c_1} + \frac{(\Delta V)^2}{a^2 k_2 c_2} \right) + \left(\frac{1}{2} \frac{(\Delta V)^2}{a^2 k_3 c_3} - \frac{(\Delta V)^2}{a^2 k_2 c_2} + \frac{1}{2} \Delta V + V_L \right) \right] - \frac{1}{2} c_3 z_3^2. \end{aligned}$$

Solving for the payoff maximizing effort level, BM already showed that the stronger player decreases her effort more by a negative spillover effect. The open question remains whether players knowing their future opponent decrease their effort more than players that do not know their future opponent.

Deriving the first-order condition for payoff maximization and solving for the optimal effort level in the first round yields for players 1 and 3, respectively,

$$\begin{aligned} \frac{\partial \pi_{1,first}}{\partial z_1} &= \frac{1}{a} \left(\frac{1}{2} \frac{(\Delta V)^2}{a^2 k_1 c_1} - \frac{(\Delta V)^2}{a^2 k_3 c_3} + \frac{1}{2} \Delta V + V_L \right) + P_1(z_1, z_2) \left(-\frac{1}{2} \frac{(\Delta V)^2}{a^2 k_1^2 c_1} \frac{\partial k_1}{\partial z_1} \right) - c_1 z_1 \\ \Rightarrow z_1^* &= \frac{1}{c_1} \left[\frac{1}{a} \left(\frac{1}{2} \frac{(\Delta V)^2}{a^2 k_1 c_1} - \frac{(\Delta V)^2}{a^2 k_3 c_3} + \frac{1}{2} \Delta V + V_L \right) - P_1(z_1, z_2) \left(\frac{1}{2} \frac{(\Delta V)^2}{a^2 k_1^2 c_1} \frac{\partial k_1}{\partial z_1} \right) \right] \\ \frac{\partial \pi_{3,first}}{\partial z_3} &= \frac{1}{a} \left[p_{113} \left(-\frac{(\Delta V)^2}{a^2 k_1 c_1} + \frac{(\Delta V)^2}{a^2 k_2 c_2} \right) + \left(\frac{1}{2} \frac{(\Delta V)^2}{a^2 k_3 c_3} - \frac{(\Delta V)^2}{a^2 k_2 c_2} + \frac{1}{2} \Delta V + V_L \right) \right] \\ &\quad + P_3(z_3, z_4) \left[-\frac{1}{2} \frac{(\Delta V)^2}{a^2 k_3^2 c_3} \frac{\partial k_3}{\partial z_3} \right] - c_3 z_3 \\ \Rightarrow z_3^* &= \frac{1}{c_3} \left[\frac{1}{a} \left(p_{113} \left(-\frac{(\Delta V)^2}{a^2 k_1 c_1} + \frac{(\Delta V)^2}{a^2 k_2 c_2} \right) + \frac{1}{2} \frac{(\Delta V)^2}{a^2 k_3 c_3} - \frac{(\Delta V)^2}{a^2 k_2 c_2} + \frac{1}{2} \Delta V + V_L \right) \right. \\ &\quad \left. - P_3(z_4, z_4) \left(\frac{1}{2} \frac{(\Delta V)^2}{a^2 k_3^2 c_3} \frac{\partial k_3}{\partial z_3} \right) \right]. \end{aligned}$$



Hence, if player 3 knew she would play against player 1 in the final, that is, $p_{1|3} = 1$, she would choose the optimal effort based on the same first-order condition. In contrast, if there is a positive probability that player 1 loses against player 2, she will incorporate this in her optimal choice.

Like in the short model, we observe that in the long model that incorporates both factors, the shadow effect is stronger for the player knowing her future opponent compared to not knowing her. In contrast, the spillover effect is not affected by certainty about the future opponent. The shadow effect and spillover effects equal

$$\begin{aligned}\frac{\partial z_1}{\partial c_3} &= \frac{1}{c_1} \frac{1}{a} \frac{(\Delta V)^2}{a^2 k_3 c_3^2}, & \frac{\partial z_1}{\partial k_1} &= \frac{1}{c_1} \left[\frac{1}{a} \left(-\frac{1}{2} \frac{(\Delta V)^2}{a^2 k_1^2 c_1} \right) + P_1(z_1, z_2) \left(\frac{1}{4} \frac{(\Delta V)^2}{a^2 k_1^3 c_1} \frac{\partial k_1}{\partial z_1} \right) \right], \\ \frac{\partial z_3}{\partial c_1} &= \frac{1}{c_3} \frac{1}{a} p_{1|3} \frac{(\Delta V)^2}{a^2 k_1 c_1^2}, & \frac{\partial z_3}{\partial k_3} &= \frac{1}{c_3} \left[\frac{1}{a} \left(-\frac{1}{2} \frac{(\Delta V)^2}{a^2 k_3^2 c_3} \right) + P_3(z_3, z_4) \left(\frac{1}{4} \frac{(\Delta V)^2}{a^2 k_3^3 c_3} \frac{\partial k_3}{\partial z_3} \right) \right].\end{aligned}$$

Considering the special case $c_1 = c_3 = \tilde{c}$ and $k_1 = k_3 = \tilde{k}$ to investigate whether the player knowing or expecting her future opponent is stronger affected by the shadow and spillover effect, we can derive

$$\begin{aligned}\frac{\partial z_1}{\partial c_3} &= \frac{(\Delta V)^2}{a^3 \tilde{k} \tilde{c}^3}, & \frac{\partial z_1}{\partial k_1} &= \frac{1}{\tilde{c}} \left[\frac{1}{a} \left(-\frac{1}{2} \frac{(\Delta V)^2}{a^2 \tilde{k}^2 \tilde{c}} \right) + P_1(z_1, z_2) \left(\frac{1}{4} \frac{(\Delta V)^2}{a^2 \tilde{k}^3 \tilde{c}} \frac{\partial \tilde{k}}{\partial z_1} \right) \right], \\ \frac{\partial z_3}{\partial c_1} &= p_{1|3} \frac{(\Delta V)^2}{a^3 \tilde{k} \tilde{c}^3}, & \frac{\partial z_3}{\partial k_3} &= \frac{1}{\tilde{c}} \left[\frac{1}{a} \left(-\frac{1}{2} \frac{(\Delta V)^2}{a^2 \tilde{k}^2 \tilde{c}} \right) + P_3(z_3, z_4) \left(\frac{1}{4} \frac{(\Delta V)^2}{a^2 \tilde{k}^3 \tilde{c}} \frac{\partial \tilde{k}}{\partial z_3} \right) \right].\end{aligned}$$

Thus, the shadow effect is stronger if the player knows her future opponent, whereas the spillover effect is not affected by (un)certainty about the future opponent. Summarizing, the model that incorporates both, shadow and spillover effect, leads to the same hypotheses.



APPENDIX C: ADDITIONAL REGRESSIONS

See Tables C1–C3.

TABLE C1 Regressions of male stronger player's winning probability.

Variables	Dependent variable: Stronger player wins (0% or 100%)					
	(1)	(2)	(3)	(4)	(5)	(6)
<i>Constant</i>	62.79*** (1.055)	62.29*** (1.117)	60.32*** (0.994)	−2.909 (13.58)	61.01*** (0.913)	56.53*** (2.200)
<i>ExpFutureOppRank</i>	0.193*** (0.0226)	0.197*** (0.0234)	0.150*** (0.0481)	0.197*** (0.0205)	0.226*** (0.0217)	0.192*** (0.0223)
<i>PastGamesStrong</i>	−0.309*** (0.0411)		−0.302*** (0.0406)	−0.282*** (0.0390)	−0.243*** (0.0410)	−0.298*** (0.0399)
<i>PastGamesWeak</i>	0.243*** (0.0386)		0.240*** (0.0391)	0.272*** (0.0399)	0.287*** (0.0434)	0.239*** (0.0374)
<i>RankRatio</i>	0.186*** (0.0596)	0.195*** (0.0707)	0.184*** (0.0575)	0.182*** (0.0623)	0.177*** (0.0583)	0.157*** (0.0580)
<i>PastSetsStrong</i>		−3.250*** (0.808)				
<i>PastSetsWeak</i>		1.903*** (0.694)				
<i>GrandSlam</i>			6.839*** (1.661)			
<i>GrandSlam × ExpFutureOppRank</i>			0.0437 (0.0512)			
<i>LnPurse</i>				4.231*** (0.890)		
<i>DiffPrize</i>					0.0100 (0.00986)	
<i>BestRank</i>						6.373*** (2.001)
Round fixed effects	x	x	x	x	x	x
Tournament-year fixed effects	x	x				x
Surface and court-type fixed effects			x	x	x	
<i>Observations</i>	11,583	10,165	11,583	10,275	9920	11,583
<i>R</i> ²	0.057	0.056	0.044	0.042	0.042	0.058

Note: Robust standard errors clustered on tournament-year level in parentheses.

****p* < .01; ***p* < .05; **p* < .1.

TABLE C2 Regressions of female stronger player's winning probability.

Variables	Dependent variable: Stronger player wins (0% or 100%)					
	(1)	(2)	(3)	(4)	(5)	(6)
<i>Constant</i>	58.79*** (0.968)	58.27*** (0.967)	54.60*** (1.942)	38.47** (15.93)	58.06*** (1.526)	59.47*** (2.455)
<i>ExpFutureOppRank</i>	0.180*** (0.0200)	0.175*** (0.0204)	0.234*** (0.0525)	0.186*** (0.0213)	0.194*** (0.0221)	0.180*** (0.0201)
<i>PastGamesStrong</i>	−0.277*** (0.0575)		−0.265*** (0.0552)	−0.204*** (0.0580)	−0.157*** (0.0555)	−0.278*** (0.0572)
<i>PastGamesWeak</i>	0.223*** (0.0640)		0.194*** (0.0626)	0.221*** (0.0650)	0.256*** (0.0662)	0.222*** (0.0641)
<i>RankRatio</i>	0.336*** (0.0323)	0.332*** (0.0339)	0.339*** (0.0315)	0.333*** (0.0319)	0.331*** (0.0324)	0.341*** (0.0424)
<i>PastSetsStrong</i>		−2.793* (1.662)				
<i>PastSetsWeak</i>		1.111 (1.593)				
<i>GrandSlam</i>			5.231*** (1.829)			
<i>GrandSlam</i> × <i>ExpFutureOppRank</i>			−0.0664 (0.0547)			
<i>LnPurse</i>				1.179 (0.975)		
<i>DiffPrize</i>					−0.0200* (0.0107)	
<i>BestRank</i>						−0.694 (2.435)
Round fixed effects	x	x	x	x	x	x
Tournament-year fixed effects	x	x				x
Surface and court-type fixed effects			x	x	x	
<i>Observations</i>	8786	8041	8786	8382	8235	8786
<i>R</i> ²	0.045	0.042	0.036	0.034	0.034	0.045

Note: Robust standard errors clustered on tournament-year level in parentheses.

****p* < .01; ***p* < .05; **p* < .1.



TABLE C3 Regressions of stronger player's winning probability (separated by state of information).

Variables	Dependent variable: Stronger player wins (0% or 100%)			
	(1) Unknown	(2) Unknown	(3) Known	(4) All
<i>Constant</i>	61.00*** (1.146)	59.93*** (1.718)	68.48*** (1.466)	62.62*** (0.985)
<i>ExpFutureOppRank</i>	0.198*** (0.0238)	0.260*** (0.0516)		
<i>Female</i>	−3.836*** (1.355)	−1.233 (2.171)	−0.784 (1.646)	−4.034*** (1.292)
<i>Female × ExpFutureOppRank</i>	0.0186 (0.0316)	−0.0898 (0.0668)		
<i>Plays</i>		1.564 (1.604)		
<i>Plays × ExpFutureOppRank</i>		−0.0792 (0.0501)		
<i>Plays × Female</i>		−4.186* (2.483)		
<i>Plays × Female × ExpFutureOppRank</i>		0.153** (0.0736)		
<i>FutureOppRank</i>			0.0803*** (0.0177)	
<i>Female × FutureOppRank</i>			−0.0363 (0.0279)	
<i>(Exp)FutureOppRank</i>				0.187*** (0.0221)
<i>Known</i>				1.212 (1.139)
<i>Known × (Exp)FutureOppRank</i>				−0.0940*** (0.0280)
<i>Female × (Exp)FutureOppRank</i>				0.0217 (0.0309)
<i>Known × Female</i>				3.868** (1.900)
<i>Known × Female × (Exp)FutureOppRank</i>				−0.0599 (0.0444)
<i>PastGamesStrong</i>	−0.293*** (0.0427)	−0.297*** (0.0426)	−0.334*** (0.0502)	−0.300*** (0.0343)
<i>PastGamesWeak</i>	0.245*** (0.0416)	0.246*** (0.0416)	0.296*** (0.0496)	0.264*** (0.0353)
<i>RankRatio</i>	0.203***	0.202***	0.332***	0.234***

(Continues)



TABLE C3 (Continued)

Variables	Dependent variable: Stronger player wins (0% or 100%)			
	(1) Unknown	(2) Unknown	(3) Known	(4) All
	(0.0589)	(0.0585)	(0.0314)	(0.0539)
Round fixed effects	x	x	x	x
Tournament-year fixed effects	x	x	x	x
Observations	13,068	13,068	7183	20,251
R^2	0.048	0.049	0.063	0.047

Note: Robust standard errors clustered on tournament-year level in parentheses.

*** $p < .01$; ** $p < .05$; * $p < .1$.